INSTRUCTION MANUAL
FOR
VSWR AUTOTESTERS
AND BRIDGES

WILTRON COMPANY

PALO ALTO, CALIFORNIA

INSTRUCTION MANUAL
FOR
VSWR AUTOTESTERS
AND BRIDGES

Copyright 1971

WILTRON COMPANY
for better electronics measurements

930 EAST MEADOW DRIVE
PALO ALTO, CALIFORNIA 94303
(415) 321-7428

TABLE OF CONTENTS

Section		Page
I	GENERAL INFORMATION	
1-1	Introduction	1-1
1-2	General Description	1-1
1-3	63 and 67 Series VSWR Description	1-1
1-4	VSWR Bridges Description	1-2
II	HOW TO MAKE VSWR MEASUREMENTS	
2-1	Making the Test Set-Up	2-1
2-2	Use of Calibration Overlays	2-3
2-3	Calibration for VSWR Swept Frequency Measurements	2-3
2-4	Measurement	2-4
2-5	Loss Substitution Method of Making VSWR Measurements	2-4
2-6	Calibrated Mismatch Method	2-4
2-7	VSWR Measurements Using Logarithmic-Linear Display Instruments	2-7
2-8	Calibration	2-7
2-9	Measurement	2-7
2-10	VSWR Measurements at Very Low RF Levels	2-7
2-11	Calibration	2-9
2-12	Measurement	2-9
III	ACCURACY CONSIDERATIONS	
3-1	Accuracy Limitations in Measuring Small VSWR's	3-1
3-2	Accuracy Limitations in Measuring Large VSWR's	3-1
3-3	Types of Connectors	3-1
3-4	Uniformity of RF Level.	3-2
3-5	Use of Calibrated Mismatch	3-2
IV	OTHER APPLICATIONS	
4-1	Reflection Coefficient and Return Loss	4-1
4-2	Simultaneous Frequency Response and VSWR Display	4-1
V	PERFORMANCE VERIFICATION AND MAINTENANCE	
5-1	Test Equipment Required.	5-1
5-2	Directivity (Accuracy of Balance)	5-1
5-3	Output VSWR	5-1
5-4	Maintenance	5-1

SECTION I
GENERAL INFORMATION

1-1 INTRODUCTION

This manual covers both the WILTRON VSWR AUTOTESTERS and VSWR BRIDGES. The procedure for using WILTRON VSWR AUTOTESTERS is the same as that used for WILTRON VSWR BRIDGES except that the VSWR AUTOTESTER has a built-in detector whereas the bridge uses an external detector.

Much valuable information is contained in this manual on this new swept frequency VSWR measurement method. This measurement technique offers advantages of improved accuracy, faster measurements and versatility and yet is far easier to use than previous techniques using slotted lines, reflectometers, and dual directional couplers. Calibration is simple and more accurate by the use of attenuators between the source and the bridge input eliminating the need for calibrated mismatches on the test port which introduces the error of the VSWR of the input connector of the mismatch.

WILTRON VSWR BRIDGES and VSWR AUTOTESTERS provide the highest directivity, and widest frequency range of any VSWR measuring devices in the industry. The WILTRON Model 63N50 for example covers the entire range of 10MHz to 3500 MHz while other WILTRON VSWR BRIDGES and VSWR AUTOTESTERS cover 50kHz to 12.4GHz.

1-2 GENERAL DESCRIPTION

WILTRON VSWR AUTOTESTERS and VSWR BRIDGES are instruments for making swept or fixed frequency measurements of voltage standing wave ratio (VSWR) over unusually large frequency ranges.

Nearly every microwave component or part of a microwave system -- antennas, amplifiers, couplers, matching devices, splitters, attenuators, filters, and terminations require VSWR tests. Impedance matching of HF, VHF, and UHF devices can be made using appropriate WILTRON VSWR BRIDGES and VSWR AUTOTESTERS.

Both VSWR BRIDGES and VSWR AUTOTESTERS are similar to Wheatstone bridges except they can inherently work at RF frequencies and are also accurate at imbalance. The term AUTOTESTER is used to differentiate BRIDGES with built-in detectors from BRIDGES with RF Output ports. The VSWR AUTOTESTER is the most complete instrument and simplest to use, but if further RF processing such as amplification or network analysis is desired, a VSWR BRIDGE without an Internal RF detector offers greater flexibility. Also over some frequency ranges it is impractical for WILTRON to build in the detector.

1-3 63 AND 67 SERIES VSWR AUTOTESTERS

The WILTRON 63 Series Instruments are VSWR AUTOTESTERS, (VSWR BRIDGES with a built-in detector), for making VSWR measurements over the unusually large frequency range of 10MHz to 3.5GHz. The WILTRON 67 Series Instruments are WILTRON's second line of VSWR AUTOTESTERS, covering the range from 10MHz to 1000MHz. These frequency ranges vary somewhat according to the connector installed and characteristic impedance as described in the Tables following Section I.

Physical Description

The WILTRON 63 Series and 67 Series VSWR AUTOTESTERS differ in physical appearance according to the different construction techniques necessary for the frequency ranges covered. The 63 Series are small, rectangular blocks with precision machined internal cavity and cover. A precision stainless steel connector is

Physical Description - VSWR AUTOTESTERS - Continued

provided for connection to the DEVICE UNDER TEST. On the 67 Series a wide variety of connector types are available. The DETECTED VSWR OUTPUT connector is a female BNC. The cylindrical projection opposite the DEVICE UNDER TEST port is the built-in precision reference termination.

Electrical Description

The Model 63 and 67 Series VSWR AUTOTESTERS are shown in Figure 1-1. Incident voltage applied to the DEVICE UNDER TEST is half (6dB below) the voltage introduced at the RF INPUT. Reflected voltage from the DEVICE UNDER TEST is applied to an internal diode detector whose DC OUTPUT is proportional to the square of the reflected voltage. This square law response holds for incident voltage from -19dBm to the diode's lowest level of sensitivity.

A Log-Linear Level meter such as the WILTRON Model 501 can also be used to extend the dynamic range of the VSWR AUTOTESTER as much as 60dB.

Caution should be exercised with the 75 ohm versions of the 67 Series when BNC connectors are used as the RF INPUT connector and the DEVICE UNDER TEST BNC connector (if that option is installed) will mechanically mate with a 50 ohm cable and connector. The resulting impedance mismatch can result in unsatisfactory electrical performance and may destroy the 75 ohm connector. In all cases, the DC OUT connector is a 50 ohm type BNC.

1-4 VSWR BRIDGES DESCRIPTION

The various models of VSWR BRIDGES are used for VSWR measurements in the microwave region of 3GHz to 12.4GHz as shown in Table 1-6. These bridges provide an RF output port for use with external detectors or network analyzers such as the WILTRON 310/311. The VSWR is displayed as a function of frequency on an oscilloscope when detected at the RF output port or as a Smith Chart display when used with a network analyzer.

Physical Descriptions

The various models of VSWR BRIDGES are small rectangular blocks with a precision machined cavity and cover. A wide variety of connector configurations are provided to optimize these BRIDGES for different uses. See Tables 1-1 through 1-6.

The cylindrical projection opposite the DEVICE UNDER TEST connector is the built in precision reference termination.

Electrical Description

The Series 60, 64, 65 and 66 VSWR BRIDGES have the same analogy to Wheatstone Bridges as do the 63 and 67 Series AUTOTESTERS. They have an RF output port rather than a detected output. All of them include built-in reference terminations. The high directivity provides high accuracy for measuring low VSWR's while the wide frequency ranges and proportional output provide for convenient swept frequency testing.

The Model 68 VSWR BRIDGES differ from other WILTRON Bridges in that they are symmetrical RF transformers as shown in Figure 1-3. The insertion loss of the 68 Series VSWR BRIDGES is only 3dB compared to 6dB for all other WILTRON Series. A built-in reference termination

Electrical Description - VSWR BRIDGES - Continued

is included, but an external detector is required. The transformer type construction makes it possible to achieve the high directivity and low insertion loss figures shown in Table 1-3.

TABLE 1-1

63 SERIES

Highest performance VSWR Autotester. Directivity typically better than 43 dB. Accuracy typically .0075 ± 3% ρ. Can be further optimized for special frequency bands. Type N precision stainless steel connectors conform to MIL-G-39012. Includes built-in reference termination and built-in negative detector.

ACCURACY: 0.01 ± 6% ρ where ρ is the reflection coefficient being measured.

INPUT CONNECTOR: Type N Female, Stainless Steel

VSWR OUTPUT POLARITY: Negative

DETECTOR OUTPUT CONNECTOR: BNC Female

VSWR OUTPUT TIME CONSTANT: 2 μs

INSERTION LOSS: 6 dB (from input to test port)

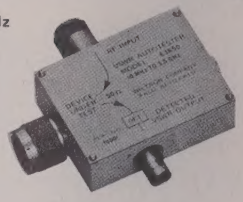
MAXIMUM POWER INPUT: 1/2 Watt

WEIGHT: 12 Ounces

DIMENSIONS: 2-5/8" x 2" x 7/8" excluding connectors

WILTRON'S accuracy specification includes the effect of the built-in precision termination.

10 MHz to 3500 MHz (useful to at least 4000 MHz)



Model 63N50

Recommended accessories:
WILTRON Model 501
Logarithmic Loss Meter and
WILTRON Sweep Generators.
(See Pages 8 – 16, '71 Catalog.)

Model	Test Port Connector (Precision Stainless Steel)	Freq. Range in MHz	Input Z ohms	Directivity dB
63N50	Type N Male	10-3500	50	40
63NF50	Type N Female	10-3500	50	40
63S50	SMA Male	10-3500	50	40
63SF50**	SMA Female	10-3500	50	40
63G50	GR 900	10-3500	50	40
63A50	APC 7	10-3500	50	40
63N75	Type N Male	10-2000	75	40
63NF75	Type N Female	10-2000	75	40

**Use opposite sex with adapter if convenient due to possible wear factor of connector under extended usage.

TABLE 1-2

67 SERIES

Inexpensive VSWR autotester. Includes built-in reference termination and built-in negative detector.

ACCURACY: 0.01 ± 10% ρ where ρ is the reflection coefficient being measured.

INPUT CONNECTOR: BNC Female or Type N Female

VSWR OUTPUT POLARITY: Negative

DETECTOR OUTPUT CONNECTOR: BNC Female

VSWR OUTPUT TIME CONSTANT: 2 μs

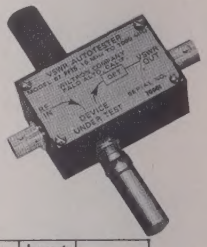
INSERTION LOSS: 6 dB (from input to test port)

MAXIMUM POWER INPUT: 1/2 Watt

WEIGHT: 6 Ounces

DIMENSIONS: 2-1/4" x 1-3/8" x 1-1/8" excl. connectors

10 MHz to 1000 MHz



Model 67FF75

Recommended accessories:
WILTRON Sweep Generators

Model	Test Port Connector	Freq. Range in MHz	Input Z ohms	Directivity dB
67N50	Type N Male	10-1000	50	40
67NF50	Type N Female	10-1000	50	40
67B50	BNC Male	10-1000	50	40
67BF50	BNC Female	10-1000	50	40
67T50	TNC Male	10-1000	50	40
67TF50	TNC Female	10-1000	50	40
67N75	Type N Male	10-1000	75	40
67NF75	Type N Female	10-1000	75	40
67B75	BNC Male	10-1000	75	40
67BF75	BNC Female	10-1000	75	40
67T75	TNC Male	10-1000	75	40
67TF75	TNC Female	10-1000	75	40
67FF75	Type F Female	10-1000	75	40

*WILTRON'S accuracy specification is an overall statement of the measurement accuracy; it includes the effect of the built-in precision termination, the built-in detector, and the effect of the VSWR of the Autotester connector.

WILTRON VSWR BRIDGES

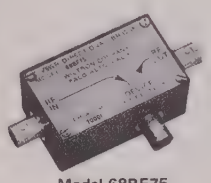
SPECIFICATIONS

TABLES 1-3, 1-4, 1-5 and 1-6

68 SERIES VSWR Bridge for HF Communictions or video and baseband

Model	Test Port Connector	Input Z ohms	Directivity dB
68B50	BNC Male	50	50
68BF50	BNC Female	50	50
68T50	TNC Male	50	50
68TF50	TNC Female	50	50
68B75	BNC Male	75	50
68BF75	BNC Female	75	50
68T75	TNC Male	75	50
68TF75	TNC Female	75	50

50 kHz to 32 MHz



Model 68BF75

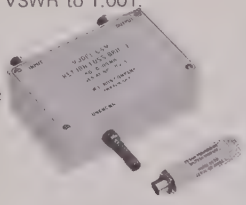
INPUT AND OUTPUT CONNECTOR: BNC Female
INSERTION LOSS: 3 dB (from input to test port)
MAXIMUM POWER INPUT: ½ Watt
WEIGHT: 6 Ounces
DIMENSIONS: 2-1/4" x 1-3/8" x 1-1/8" excluding connectors
Recommended Accessory: Wiltron Model 71B50 Detector or 71B75 for 75 ohm system.

66 SERIES IF bridge has highest directivity, measures VSWR to 1.001.

Model	Test Port Connector	Input Z ohms	Directivity dB
66W75	WE 801A	75	60
66M75	WE 439A	75	60

*Standard external reference termination included, 1.001 VSWR

50 MHz to 100 MHz



Model 66W75

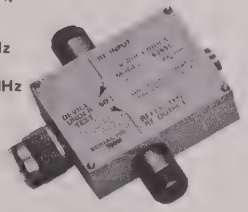
INPUT AND OUTPUT CONNECTOR: Western Electric 509A or 567A
INSERTION LOSS: 6 dB (from input to test port)
MAXIMUM POWER INPUT: ½ Watt
WEIGHT: 13 Ounces
DIMENSIONS: 4"x2-5/8"x1-7/16" excluding connectors

60 SERIES VSWR Bridge with largest band width.

Model	Test Port Connector	Input Z ohms	Directivity dB
60N50	Type N Male	50	40
60NF50	Type N Female	50	40
60S50	SMA Male	50	40
60SF50	SMA Female*	50	40
60G50	GR 900	50	40
60A50	APC 7	50	40

*Use opposite sex with adapter if convenient due to possible wear factor of connector under extended usage.

5 MHz to 2000 MHz



Model 60N50

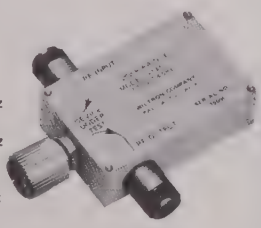
INPUT AND OUTPUT CONNECTOR: Type N Female Stainless Steel
INSERTION LOSS: 6 dB (from input to test port)
MAXIMUM POWER INPUT: ½Watt
WEIGHT: 12 Ounces
DIMENSIONS: 2-5/8" x 2" x 7/8" excluding connectors
Recommended Accessory: Wiltron Model 73 or 74 Series R.F. Detector.

64 and 65 SERIES VSWR Bridge used with detector or network analyzer. Extends bridge accuracy and simplicity through X-band.

Model	Test Port Connector (Precision Stainless Steel)	Input Z ohms	Directivity dB
64G50	GR 900	50	36
64A50	APC 7	50	36
65A50	APC 7	50	36

3 GHz to 8 GHz

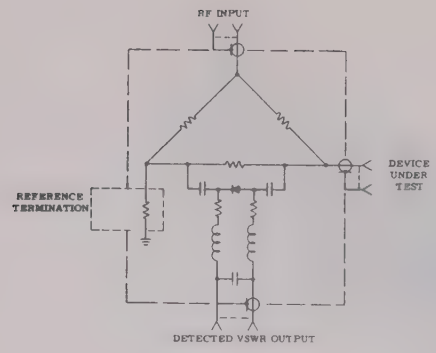
7 GHz to 12.4 GHz



Model 65A50

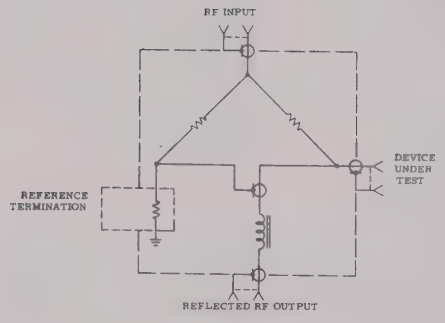
INPUT AND OUTPUT CONNECTOR: Type N Female Stainless Steel
INSERTION LOSS: 6 dB (from input to test port)
MAXIMUM POWER INPUT: ½ Watt
WEIGHT: 10 Ounces
DIMENSIONS: **Model** 64G50: 1-3/4" x 1-1/2" x 1-1/8" excluding connectors **Model** 65A50 and 64A50: 2-7/8" x 2" x 7/8" excluding connectors
Recommended Accessory: Wiltron Model 74N50 R.F. Detector.

Attractive wooden Storage Case supplied with Series 60, 63, 64 and 65.



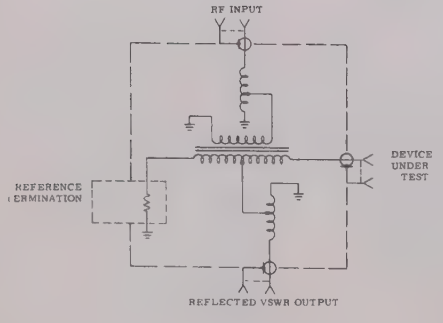
WILTRON VSWR AUTOTESTERS
SERIES 63 and 67

Figure 1-1



WILTRON VSWR BRIDGES
SERIES 60, 64, 65, 66

Figure 1-2



WILTRON VSWR BRIDGES
SERIES 68

Figure 1-3

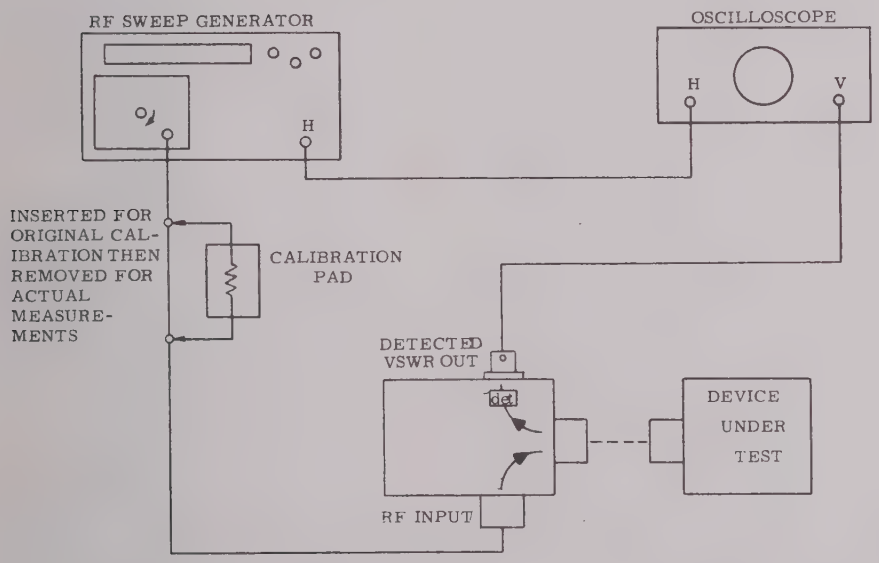
SECTION II

HOW TO MAKE VSWR MEASUREMENTS

(VSWR MEASUREMENTS USING A CALIBRATED OSCILLOSCOPE OVERLAY)

2-1 MAKING THE TEST SET-UP

Connect the sweep generator, oscilloscope, VSWR AUTOTESTERS or VSWR BRIDGE and the device under test as shown in Figure 2-1 using coaxial cables of the same impedance as the sweeper and the VSWR AUTOTESTER to connect to the input and output ports of the VSWR AUTOTESTER. The sweep generator should have a leveled output of at least 1 volt rms through the swept range. The oscilloscope should have a sensitivity of 100μV per cm, but most measurements can be made with a 1mV per cm sensitivity.



MAKING SWEPT FREQUENCY VSWR MEASUREMENT ON INACTIVE DEVICES USING WILTRON VSWR AUTOTESTERS

FIGURE 2-1

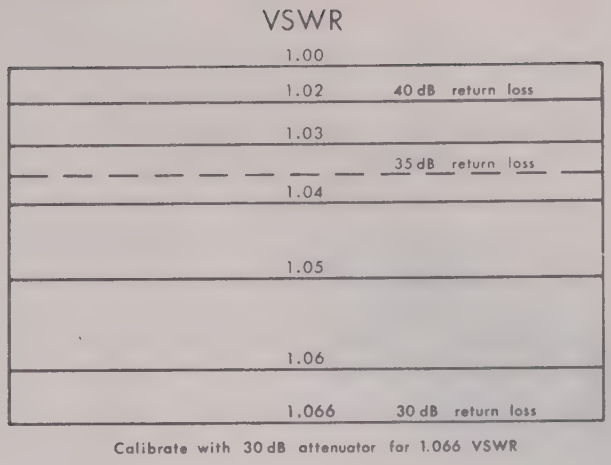


Fig. 2-2

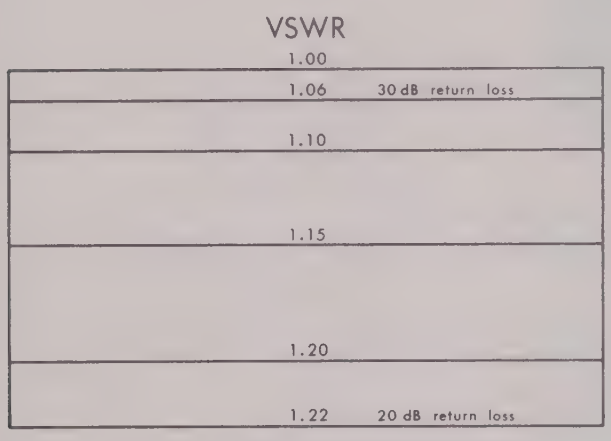


Fig. 2-3

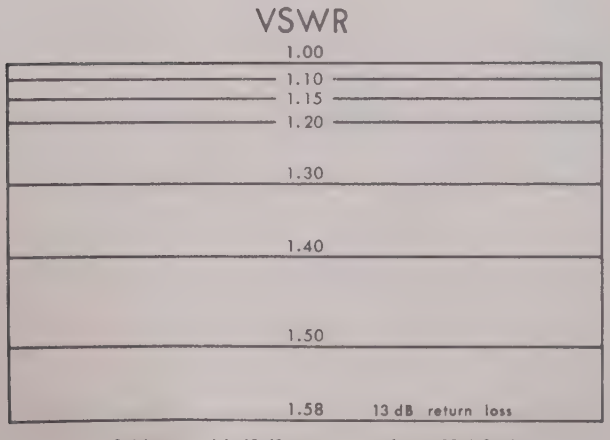


Fig. 2-4

VSWR OVERLAYS

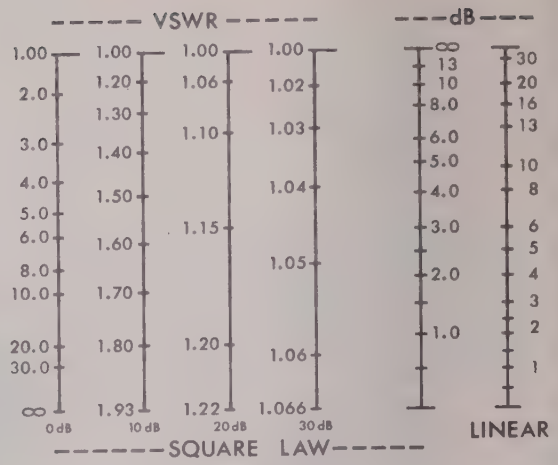


Fig. 2-5

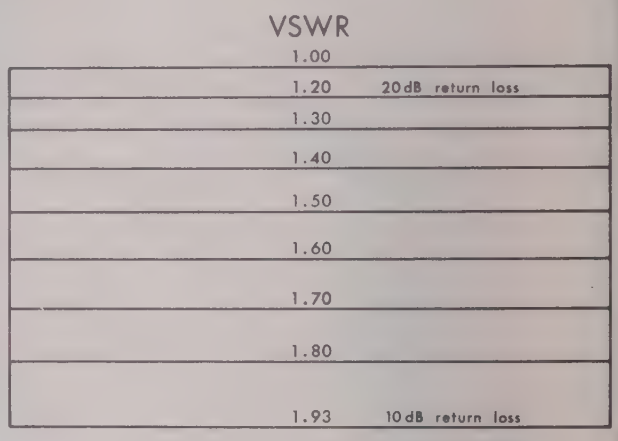


Fig. 2-6

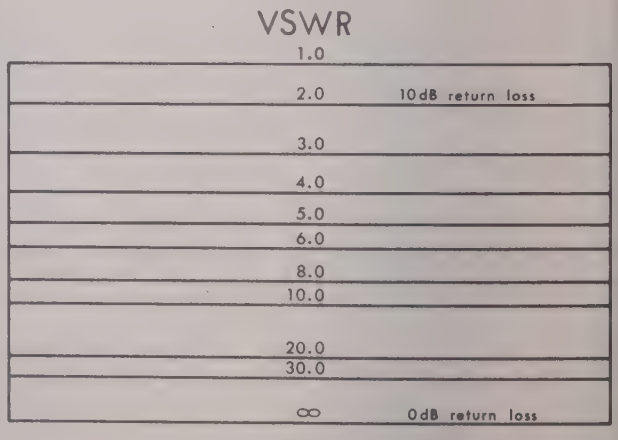


Fig. 2-7

2-2 USE OF CALIBRATION OVERLAYS

A plastic overlay sheet is furnished with each VSWR AUTOTESTER and VSWR BRIDGE. Each sheet contains 6 different calibrated graticule overlays which may be cut out to suit your particular oscilloscope. Each overlay has a VSWR range spread over 6 cm vertically with horizontal lines representing VSWR values within the range. The top line represents 1.0 VSWR and the bottom line a maximum VSWR for the range. Vertical lines are located plus and minus 5 cm from the vertical center line for setting horizontal sweep limits. Maximum input levels to the VSWR AUTOTESTER or VSWR BRIDGE for the overlay to match the detector law are shown in Table 2-1.

2-3 CALIBRATION FOR VSWR SWEPT FREQUENCY MEASUREMENTS

Calibrate the test setup with the following steps:

Adjust the sweeper RF output level to -6 dBm (see Table 2-1), select the graticule for 0dB return loss (Figure 2-7) and disconnect the device under test from the AUTOTESTER or BRIDGE.

Set the vertical sensitivity control of the oscilloscope to 1 mV/cm or more as necessary to give 6 cm deflection.

Set the horizontal sensitivity control of the oscilloscope to give 10 cm horizontal deflection.

This trace is a calibrated value of a complete mismatch, a VSWR value which approaches infinity. The RF signal trace should be horizontal and should be superimposed on the oo (0dB) line over the full swept frequency range. The return loss trace (or blanking trace) should be on the 1.0 line. Note that the signal trace may not be uniform with frequency because of sweeper imperfections, cable mismatch, etc. The trace should be calibrated for its average value to be correct, or optimized over a preferred frequency range.

Next, connect the device under test to the VSWR AUTOTESTER or VSWR BRIDGE and observe the approximate VSWR reading on the 0 dB graticule. This will indicate which of the other graticules to select for the final measurement. For example, if the reading is between 1.0 and 2.0, select the 10 dB graticule, Figure 2-6; if close to 1.0, select either the 20 or 30dB graticule, Figure 2-3 or Figure 2-2.

Having selected the graticule for the measurement, again disconnect the device under test from the VSWR AUTOTESTER or VSWR BRIDGE, increase the RF level if desired (See Table 2-1), and insert a coaxial attenuator having a loss in dB equal to that on the bottom line of the graticule, between the sweep generator and the VSWR AUTOTESTER or VSWR BRIDGE as shown in the set up Figure 2-1. Readjust the vertical sensitivity of the oscilloscope to set the signal trace on the bottom line of the graticule. This calibrates the entire system for that graticule.

When not in use graticules may be stored in the top of the wooden box supplied with the Series 60, 63, 64 and 65.

TABLE 2-1

Maximum RF input to the BRIDGE or AUTOTESTER for Square Law Operation of the VSWR Detector	-6 dBm	+4 dBm	+7 dBm	+14 dBm	+24 dBm
Return Loss Graticule	0 dB	10 dB	13 dB	20 dB	30 dB

2-4 MEASUREMENT

Remove the calibrating attenuator and reconnect the device under test to the VSWR AUTOTESTER or VSWR BRIDGE. The signal trace on the oscilloscope is the readout of VSWR for the device under test over the swept frequency range. Typical readout curves for various devices under test are shown in Figure 2-8. Any particular frequency or portion of the swept range can be investigated in detail by magnifying the sweep.

Once having made a calibration setup, different types of tests, measurements or adjustments on devices under test can be made rapidly and accurately. Quantitative VSWR values over the swept frequency range can be observed at a glance. Adjustments on a device can be made while observing the VSWR plot to obtain a desired result. Many VSWR tests require only adjusting for minimum or assuring that the minimum is within a certain value. In these cases, a single calibration at the measurement consists of seeing that the swept frequency plot does not go below the line.

2-5 LOSS SUBSTITUTION METHOD OF MAKING VSWR MEASUREMENTS

Several other methods can be used to measure return loss without using the special graticules in the previous procedure. A return loss measurement can then be quickly converted to VSWR by using the nomographs in the back of this manual.

Use the test setup shown in Figure 2-1.

a. Attach the device to be tested at the Test Port.

b. Adjust the oscilloscope sensitivity to display the sweep frequency plot.

c. Disconnect the device under test, leave the Test Port open.

d. Connect successively greater amounts of attenuation in the RF path between the RF source and the AUTOTESTER or BRIDGE until the swept frequency line on the oscilloscope screen falls on the level observed in Step b.

The amount of attenuation introduced represents the return loss of the device under test.

The Loss Substitution attenuators may also be connected between the BRIDGE RF output and the detector. When using the Loss Substitution Method care should be exercised not to damage the detector; large signals will be present in the RF path if the device under test is disconnected from the Test Port unless the RF source is attenuated or disconnected ahead of the BRIDGE.

2-6 CALIBRATED MISMATCH METHOD

The Test Port may also be calibrated to the scope graticule limit line with the following procedure using a test setup as shown in Figure 2-1 .

a. Attach the calibrated mismatch to the Test Port.

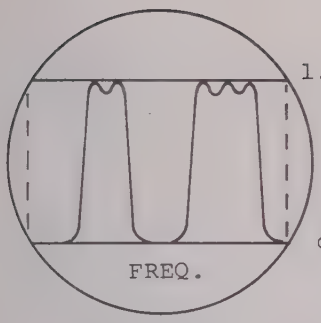
b. Adjust the scope sensitivity to display the swept frequency plot.

c. Note the limit line on the face of the oscilloscope. It is often convenient to mark the graticule to show this line for later references.

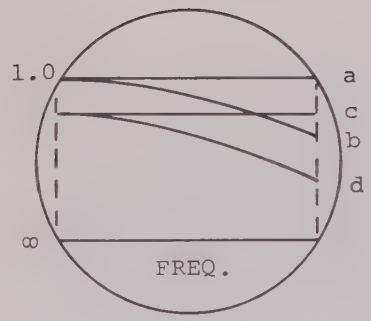
d. Remove the calibrated mismatch.

e. Connect the device to be tested to the Test Port.

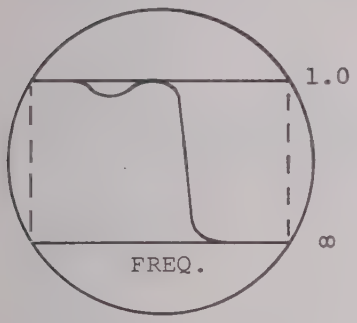
If the new swept frequency plot exceeds the limit line established in Step c., the return loss is greater than that of the calibrated mismatch, and if it does not reach the line, the return loss is better than the calibrated mismatch.



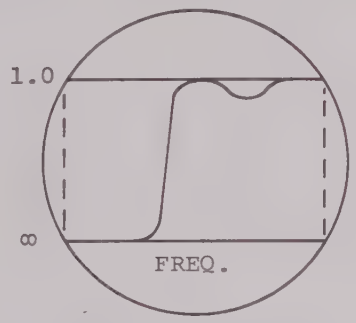
A Two Channel Aircraft Beacon and Communications Antenna



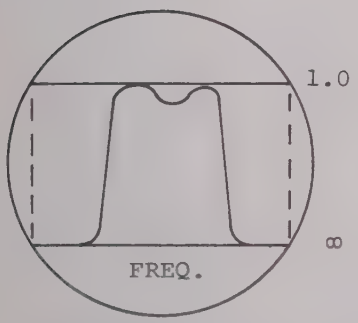
(a) 50 ohm Coax Termination
(b) 50 ohm Resistor
(c) 75 ohm Coax Termination
(d) 75 ohm Resistor



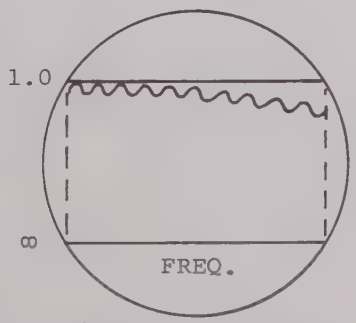
Low Pass Filter



High Pass Filter



Band Pass Filter



Long Length of 50 Ohm Coaxial Cable Terminated With 50 Ohms

FIG. 2-8 TYPICAL VSWR DISPLAYS

LOGARITHMIC LEVEL METER - MODEL 501

The WILTRON Model 501 Logarithmic Loss Meter is an ideal accessory for use with WILTRON's VSWR bridges and VSWR autotesters. It measures changes in RF power levels in the level range from −40 dBm to +20 dBm and provides readout on a linear dB scale on either the built-in panel meter or on an external oscilloscope for swept frequency measurements. The instrument is self-contained, including a power supply for 115/230V, 50-400 Hz operation.

- **Complete RF measurement system in one package**
- **Accurate low level RF measurements to −40 dBm**
- **Direct meter readout on a linear dB scale**
- **Calibrated offset**
- **60 dB of total dynamic range**

SPECIFICATIONS

FREQUENCY RANGE: Set by the external detector being used. Usable with WILTRON RF detectors from 10 MHz to 12.4 GHz.

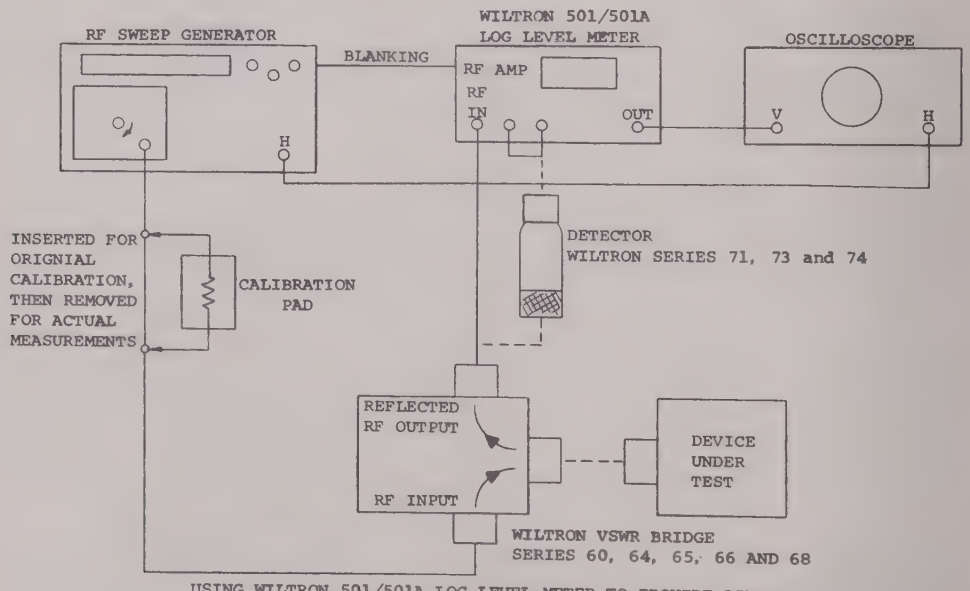
SENSITIVITY: RF Signals as detected by typical external detectors can be measured over the power range from +20 dBm to −40 dBm.

ACCURACY: ±0.3 dB ±1% of dB readout with Model 74N50 and most other detectors. When using the internal amplifier, gain compression is approximately 0.3 dB at −70 dBm and −1 dB at −80 dBm.

DISPLAYED SENSITIVITIES: 10, 5, 2, 1 or 0.5 dB per meter division.

DC OUTPUT: 5K ohms or less source impedance delivering 1 volt/div. for sensitivities of 10, 5, 2, 1 or 0.5 dB per division.

For VSWR Measurements of very small reflected RF signals (down to −80 dBm) the WILTRON Model 501A includes all the video features of the 501 but includes a built in 40 dB RF amplifier and detector operating from 5 MHz to 500 MHz.



USING WILTRON 501/501A LOG LEVEL METER TO PROVIDE LINEAR DB DISPLAY OF VSWR DIRECTLY IN DB RETURN LOSS.

FIGURE 2-9

2-7 VSWR MEASUREMENTS USING LOGARITHMIC-LINEAR DISPLAY INSTRUMENTS

Detector diodes exhibit a variable response in dc output versus incident RF power. From the noise level to approximately -15dBm, a square law response is noted, that is the dc output voltage is proportional to the square of the incident RF power. The VSWR graticules discussed in Section 2-1 are constructed, based upon this square law response. At RF power levels greater than -15dBm, the dc output voltage is directly proportional to the RF power or linear. It can be seen that if a dc amplifier's response were made variable with amplitude to respond first logarithmically to -15 dBm and then linearly, the useful dynamic range will be increased. Such an amplifier response is built-in the WILTRON Model 501. Figure 2-9 illustrates a VSWR test Setup using a Model 501.

2-8 CALIBRATION

The WILTRON Model 501 manual contains a complete calibration section for use with VSWR AUTOTESTERS and VSWR BRIDGES. The reader should consult that publication for initial calibration and detector tracking instructions.

Tracking of the detector, with an AUTOTESTER or with a BRIDGE should, however be checked from time to time by simply referencing the 501 to 0 dB with the VSWR BRIDGE or VSWR AUTOTESTER's DEVICE UNDER TEST port open circuited. An attenuator is then placed between the sweep oscillator and the AUTOTESTER or BRIDGE and the 501 should read the value of the attenuator ± it's accuracy ± the accuracy of the particular VSWR BRIDGE or VSWR AUTOTESTER being used (i.e., a 20 dB attenuator would show a 20 dB return loss reading corresponding to a 1.22 VSWR).

When selecting sweep generator power levels suitable for wide dynamic ranges, the operator should keep in mind that the loss through the VSWR BRIDGE or, VSWR AUTOTESTER (6 dB) is doubles to the detector for the case of 0 dB return loss (open or short circuit). This situation exists because the bridge circuit must be transversed twice (incident and reflected). Thus the detector will always be at a minimum of 12 dB below the sweep generator output level.

With the oscilloscope vertical sensitivity set to 1 V/cm, return loss can be read directly from the oscilloscope face in dB appropriate to the SENSITIVITY control setting on the Model 501.

2-9 MEASUREMENT

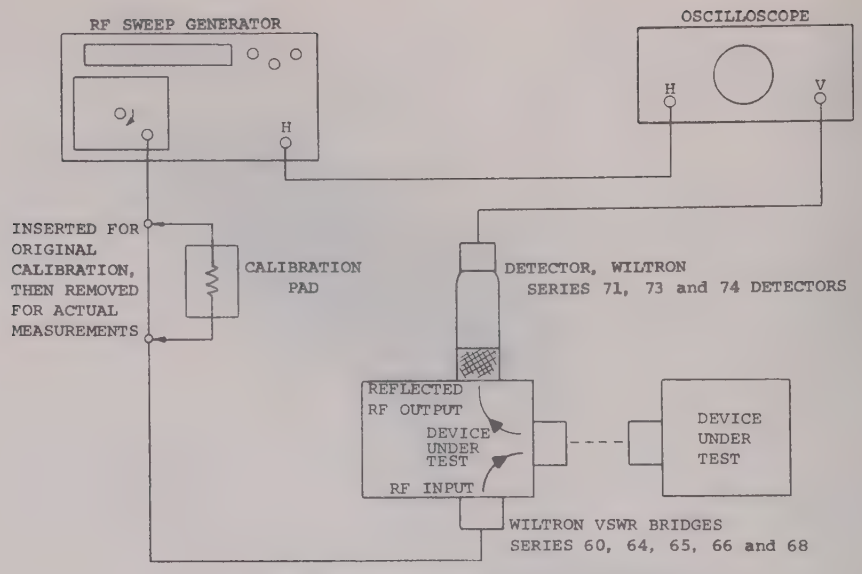
Remove the calibration attenuator and connect the device under test to the VSWR AUTOTESTER or VSWR BRIDGE. The signal trace on the oscilloscope is the linear readout of return loss in db for the device under test over the swept frequency range. Table 6-1, 6-2 and 6-3 are graphs for converting return loss in dB to VSWR. A handy nomogram is printed on the top of the wooden box supplied with the Series 60, 63, 64 and 65.

2-10 VSWR MEASUREMENTS AT VERY LOW RF LEVELS

Certain devices such as mixers, preamplifiers, very low level limiters and modulators and other devices may change their impedance characteristics with applied power level. The return loss bridges are especially useful for small signal measurements by using an amplifier prior to detection.

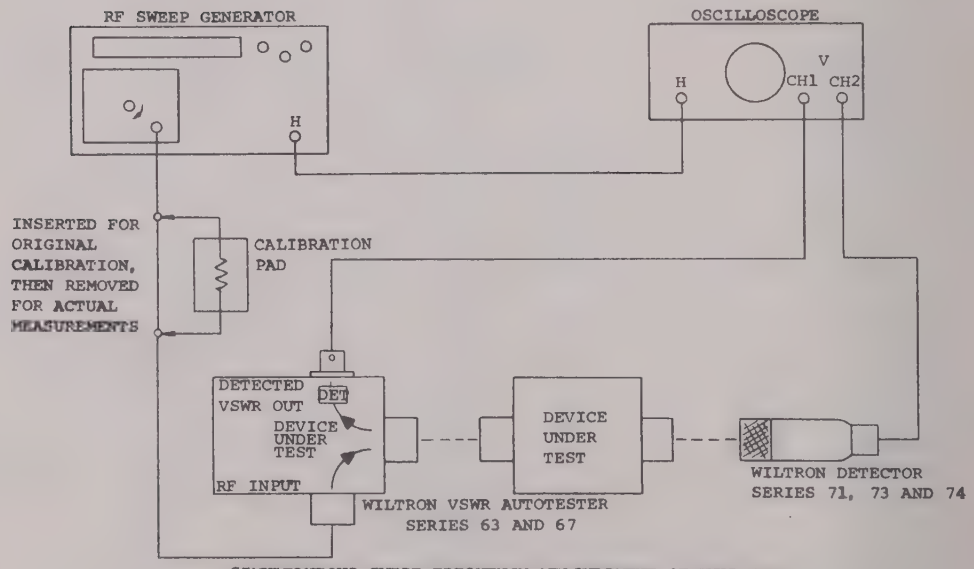
A typical small signal return loss setup is shown in Figure 2-12.

The amplifier selected for this measurements must have a dynamic range of greater than 10dB and a gain factor sufficient to



MAKING SWEPT FREQUENCY VSWR MEASUREMENTS ON INACTIVE DEVICES USING WILTRON VSWR BRIDGES

FIGURE 2-10



SIMULTANEOUS SWEPT FREQUENCY MEASUREMENT OF VSWR AND TRANSMISSION LOSS USING WILTRON VSWR AUTOTESTER.

FIGURE 2-11

2-10 VSWR MEASUREMENTS AT VERY LOW RF LEVELS Cont.

supply the detector more than -40dBm but less than -15 dBm. The sensitivity of the amplifier will determine the minimum power level that is applied to the device under test for any given VSWR of the device under test.

For example, if a mixer exhibited a VSWR of 1.22 and it was necessary to measure VSWR with no more than -60 dBm power applied, the sweep generator output is attenuated to -60 dBm with the internal or an external attenuator. The power to the mixer is -60 dBm + (-6 dB) loss through the Bridge or -66 dBm. The return loss corresponding to 1.22 VSWR is 20dB. The relfected energy again experiences a 6 dB loss through the Bridge to the amplifier. The power input to the amplifier then is -92 dBm (-60 dBm) + (-6 dB) + (-20dB) + (-6 dB) and the amplifier must have a sensitivity greater than -92 dBm.

It is also very desirable that the amplifier be gain limited to keep its output below +20 dBm under large signal inputs to avoid damage to the detector.

2-11 CALIBRATION

The sweep generator's internal attenuator or an external attenuator is used to calibrate the oscilloscope face as discussed in 2-1. However, the graticules can only be used if the gain characteristic is linear over its displayed dynamic range.

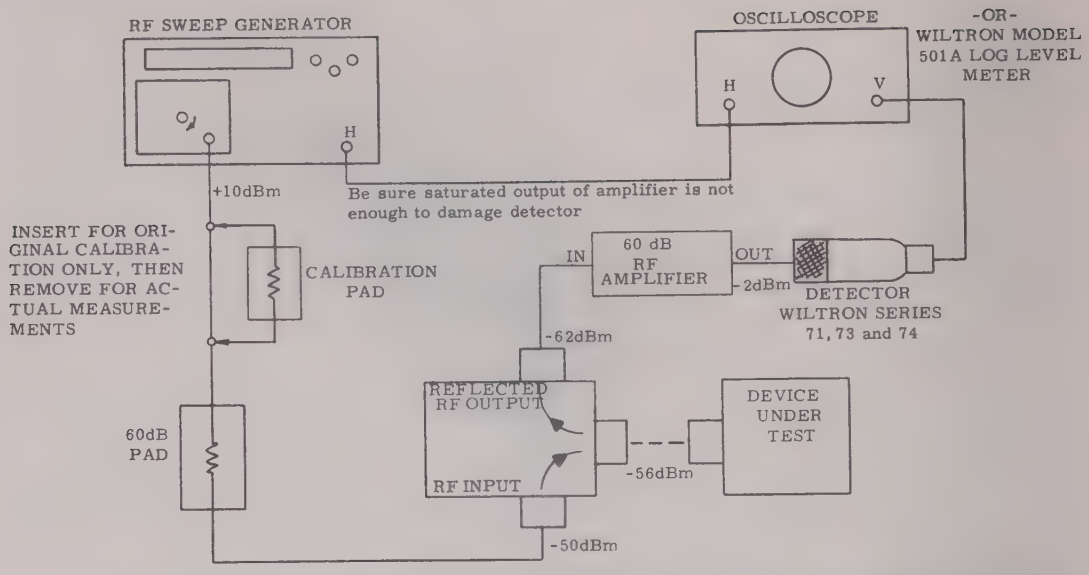
If the Model 66 VSWR BRIDGE is being used, terminate its DEVICE UNDER TEST port with the Model 66T Reference Termination while sweeping the frequency range of interest. Using the BRIDGE BALANCE ADJUST control in the bottom cover of the BRIDGE, set the oscilloscope trace for the greatest return loss and least slope across the frequency range of interest.

The WILTRON Model 501A is available with RF amplifier plug-ins suitable for this type of measurement along with the Logarithmic-linear amplifier mentioned in Section 2-2. If the Model 501A is available proceed with calibration as outlined in Section 2-2.

For calibration with a linear amplifer, open circuit the DEVICE UNDER TEST port and increase attenuation until the DC coupled oscilloscope shows both the detected RF versus frequency trace and the retrace.

2-12 MEASUREMENT

Replace the device under test connection to the BRIDGE and remove attenuation until the detected RF and retrace correspond with the deflection reference noted in calibration. The difference in attenuator settings is the return loss or VSWR (i.e., an attenuation change of 20 dB corresponds to a 1.22 VSWR).

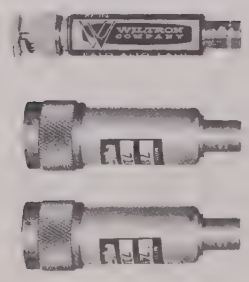


LOW LEVEL SWEPT FREQUENCY VSWR MEASUREMENTS USING RF AMPLIFIER AHEAD OF DETECTOR FOR MEASUREMENTS ON ACTIVE DEVICES SUCH AS RECEIVERS, AMPLIFIERS, ETC. WHICH MUST BE MEASURED WHILE OPERATING TO MAKE MEANINGFUL MEASUREMENTS. LEVELS SHOWN TYPICAL FOR MAKING VSWR MEASUREMENTS WITH 1.22 VSWR OVERLAY.

FIGURE 2-12

ACCESSORIES

RF DETECTORS



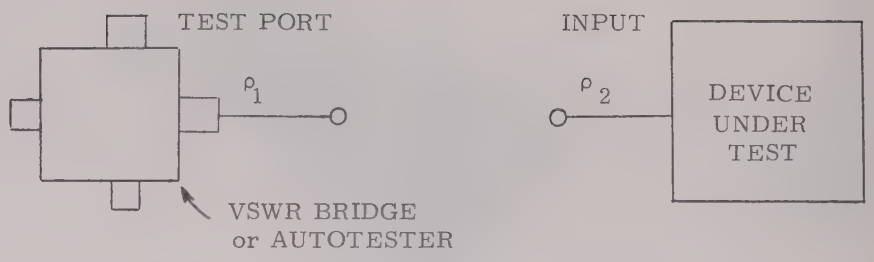
71 SERIES – WILTRON's popular general purpose detector offers unique low frequency performance down to 100 kHz and up to 3 GHz with characteristic input impedance of either 50 or 75 ohms and with positive ***or*** negative output voltage. The Model 71 B50 is WILTRON's most popular detector in this series. (It was formerly referred to as the Model 61D.)

73 SERIES—General Purpose, good high frequency coverage to 4 GHz Type N input connector, low VSWR typically 1.1

74 SERIES – WILTRON's finest quality and widest frequency range model. Has matched input and shaped polyiron for careful frequency compensation. Better low frequency performance than competing manufacturers. The Model 74 N50 is the most popular model in this series.

SPECIFICATIONS

MODEL	DESCRIPTION	FREQ. RANGE	FLATNESS	CONNECTOR IN	CONNECTOR OUT	IMPEDANCE	MAX VSWR	LOW LEVEL SENSITIVITY AT 30 dBm	HIGH LEVEL SENSITIVITY AT +13 dBm	FIELD REPLACEABLE DIODE	MAX. INPUT	OUTPUT CAPACITANCE	OUTPUT VOLTAGE POLARITY
71 B50*	Gen. Purpose (BNC Input)	100 kHz to 3 GHz	*0.5 dB	BNC Male	BNC Female	50 ohms	1.20	0.35mv/μW	1V min.	Yes*	100mw	500pF	Neg
71 B50P	"	"	"	"	"	"	"	"	"	"	"	"	Pos
71 B75	"	100 kHz to 2GHz	"	"	"	75 ohms	1.25	"	"	"	60mw	"	Neg
71 B75P	"	"	"	"	"	"	"	"	"	"	"	"	Pos
73 N50	Gen. Purpose (Type N Input)	100 kHz to 4 GHz	*0.5 dB	N Male	BNC Female	50 ohms	1.20	0.35mv/μW	1V min.	Yes	100mw	500pF	Neg
73 N50P	"	"	"	"	"	"	"	"	"	"	"	"	Pos
74 N50	Wide Band Gen Purpose	10 MHz to 12.4 GHz	±0.5 dB* 10MHz–8GHz ±0.7–12.4GHz	N Male	BNC Female	50 ohms	1.25 from 10 MHz to 8 GHz 1.50 to 12.4 GHz	0.4mv/μW	1V min.	Yes	100mw	30pF.	Neg
74 N50P	"	"	"	"	"	"	"	"	"	"	"	"	Pos



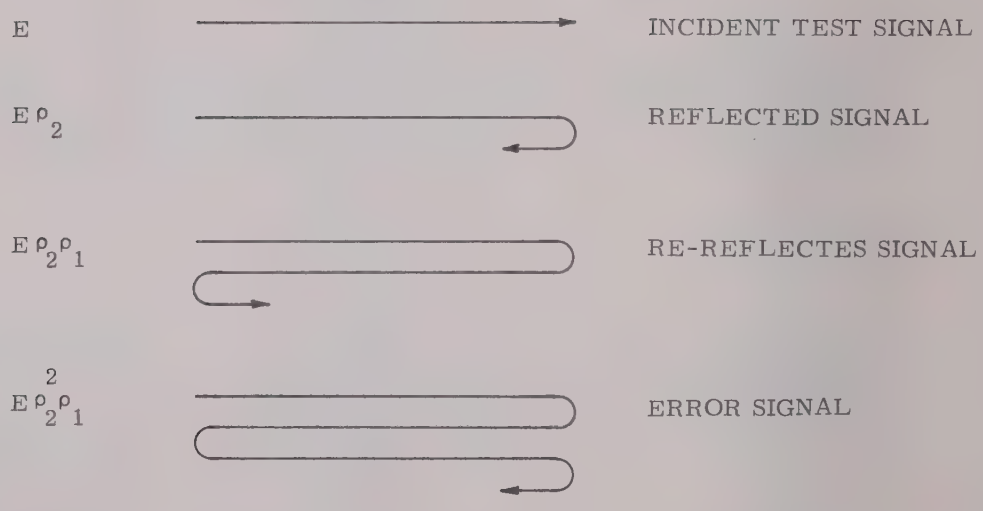


FIG. 3-1 ERROR SIGNAL GENERATED AT LARGE VSWR's

SECTION III
ACCURACY CONSIDERATIONS

3-1 ACCURACY LIMITATIONS IN MEASURING SMALL VSWR's

The theoretical limit of accuracy of an VSWR AUTOTESTER or VSWR BRIDGE, when measuring small VSWR's is its inherent directivity or balance. This is equal to the residual VSWR or uncertainty of result. If, for example, a VSWR of 1.2 were being measured with a 63 Series which has directivity of 40 dB or residual VSWR or 1.02, the instrument would read out between 1.18 and 1.22.

For VSWR AUTOTESTERS or VSWR BRIDGES without the Model 501 Amplifier, another practical limitation in the measurement of small VSWR's is the need of high sweep generator output or high oscilloscope sensitivity or a combination of both. The higher the sweep output, the greater the system sensitivity at low VSWR's. For reading VSWR's less than 1.06, it is essential to have a sweeper whose output is one volt rms or more.

The oscilloscope should have a least a 1 millivolt per centimeter sensitivity and preferably 0.1 millivolt per centimeter.

3-2 ACCURACY LIMITATIONS IN MEASURING LARGE VSWR's

In the VSWR range 1.5 to 30, the principle accuracy limitation of an VSWR AUTOTESTER or VSWR BRIDGE is its output VSWR; that is, the VSWR that the device under test "sees" when it looks back into the DEVICE UNDER TEST port. The output mismatch causes a portion of the reflected signal from the device under test to be reflected back into the device under test. When the device under test has an appreciable mismatch of its own, then it reflects a portion of this re-reflected signal back into the VSWR AUTOTESTER or VSWR BRIDGE. This signal is an error signal which can add at any phase with the original reflected signal from the device under test. Refer to Figure 3-1.

As an example of the magnitude of the error, consider an output VSWR or 1.2 from the 63 Series and an input VSWR of 1.5 for the device under test. These VSWR's are converted to reflection coefficients by the following formula:

$$\rho = \frac{S - 1}{S + 1}$$

where ρ is the reflection coefficient and S is the VSWR.

ρ_1 (reflection coefficient for output of 63) $= 0.07$

ρ_2 (for input of test device $= 0.20$

Figure 3-1 illustrates how the error signal $E\rho_1\rho_2^2$ is generated as the result of three reflections. Expressed as a percentage of the initial reflected signal $E\rho_2$:

$$\% \text{ Error} = \frac{E\rho_1\rho_2^2}{E\rho_2} \times 100\% = \rho_1\rho_2 \times 100\%$$

For the above example, the error is 1.4% of the reflection coefficient. This source of measurement uncertainty limits the VSWR measuring range to about 30:1.

3-3 TYPE OF CONNECTORS

On several VSWR AUTOTESTERS and VSWR BRIDGES, WILTRON uses on its test port the precision Type N dimensions; that is, the gap between the end of the center conductor and the outer conductor knee is nominally 0.207. For accurate results above 2GHz, it is recommended that your mating Type N connector have the same nominal dimensions (See Figure 3-2). This problem does not occur with other connectors (GR900, OSM, etc.); they have not had the same

3-3 TYPE OF CONNECTORS Cont.

evolutionary variations as the Type N. If any adaptors are used, their VSWR is included in the overall result. When low VSWR readings are to be made, check the adaptors first.

3-4 UNIFORMITY OF RF LEVEL

If the sweep generator is not adequately leveled or if there is a significant mis-match between the sweep generator and RF INPUT, the reference line on the oscilloscope trace will not be uniform with the frequency when setting up the procedure of Section II.

Amplitude variation due to mis-matches can be minimized by connecting the VSWR AUTOTESTER or VSWR BRIDGE directly onto the RF output point of the sweep output. At the extremes of the frequency range of each VSWR AUTOTESTER or VSWR BRIDGE, the reference line may have a tilt with frequency. This is due to the frequency response of the detector. The effect can be minimized by calibrating to the average value of the oscilloscope trace or alternatively calibrating the frequency region where greatest accuracy is required.

3-5 USE OF CALIBRATED MIS-MATCHES

Standard mis-matches (e.g., GR Type 900, WR 120, etc.) may be used as an alternative method of calibrating the VSWR graticules. Above about 2GHz a precision mis-match can provide a better reflection coefficient standard than an open circuit because the test port is a finite distance away from the sensing point of the bridge.

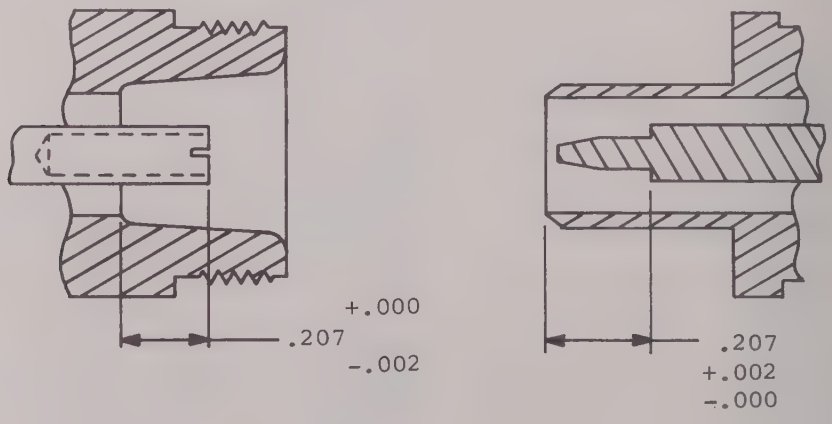


FIG. 3-2 PRECISION TYPE N CONNECTOR DIMENSIONS

SECTION IV

OTHER APPLICATIONS

4-1. REFLECTION COEFFICIENT AND RETURN LOSS

VSWR values obtained from measurements with VSWR AUTOTESTERS and VSWR BRIDGES can be converted to reflection coefficients (ρ) or return loss values in dB from the following formulas:

$$\rho = \frac{S - 1}{S + 1} \text{ where } S = \text{VSWR reading}$$

$$\text{Return Loss (dB)} = -20 \log_{10} \rho$$

Note that ρ in the above formulas represents the absolute value of the reflection coefficient, and that the return loss is actually a minus dB value although the minus sign is usually omitted.

Alternatively, the graticules can be calibrated in return loss directly using the method described in Section 2-1. But instead of calibrating with a single attenuator value for a full scale setting, switch in a series of pads 1 dB, 2 dB, 3 dB, etc., to calibrate the oscilloscope vertical display in return loss.

4-2. SIMULTANEOUS FREQUENCY RESPONSE AND VSWR DISPLAY

If the circuit on test is a two-port one, e.g., a filter or an amplifier, if a detector with termination is connected to the output of the unit on test, the detectors output will show the overall frequency response.

The VSWR output from the VSWR AUTOTESTER or VSWR BRIDGE will give simultaneously the variations in input impedance over the frequency range. Figure 2-10 shows the connection method.

Connecting the detector directly to the DEVICE UNDER TEST port will verify both the flatness of signal and the input impedance of the detector.

SECTION V
PERFORMANCE VERIFICATION AND MAINTENANCE

5-1 TEST EQUIPMENT REQUIRED

Sweep Generator - appropriate to the frequency range of the VSWR BRIDGE or VSWR AUTOTESTER, 1 V rms leveled output, e.g., WILTRON Model 610B with appropriate plug-ins.

Oscilloscope - with at least 100μV / cm sensitivity, e.g., -hp- 1202A.

Standard Termination -

Coaxial Adapters - GR to the type of connector fitted to the DEVICE UNDER TEST port of the VSWR AUTOTESTER or VSWR BRIDGE to be tested, e.g., GR Type 900 - QNP (3 required).

Precision **20** and 30 dB Attenuator Pads with Type N Connectors - e.g., Narda Type 777.

Another WILTRON VSWR AUTOTESTER or VSWR BRIDGE of the same model (previously checked for directivity).

5-2 DIRECTIVITY (ACCURACY OF BALANCE)

Use the setup of Figure 2-1 with the VSWR BRIDGE or VSWR AUTOTESTER fitted directly to the RF output jack of the sweep generator.

Using the procedure of Section 202, calibrate the system over the desired frequency range using a 30 dB pad with the WILTRON 30dB return loss graticule fitted to the oscilloscope face. Remove the attenuator pad, then connect the standard termination via an adapter to the DEVICE UNDER TEST port.

The VSWR indicated should be less than the specification noted in Table 1-1. If this reading is not obtained, check the connectors for tightness and verify that the termination and adapter used are compatible with the DEVICE UNDER TEST connector (See Section 3-3). Also check that the fingers of the center conductor have not been spread out. The termination must be bettern than 1.01 VSWR (46dB return loss) to assure 40dB reading.

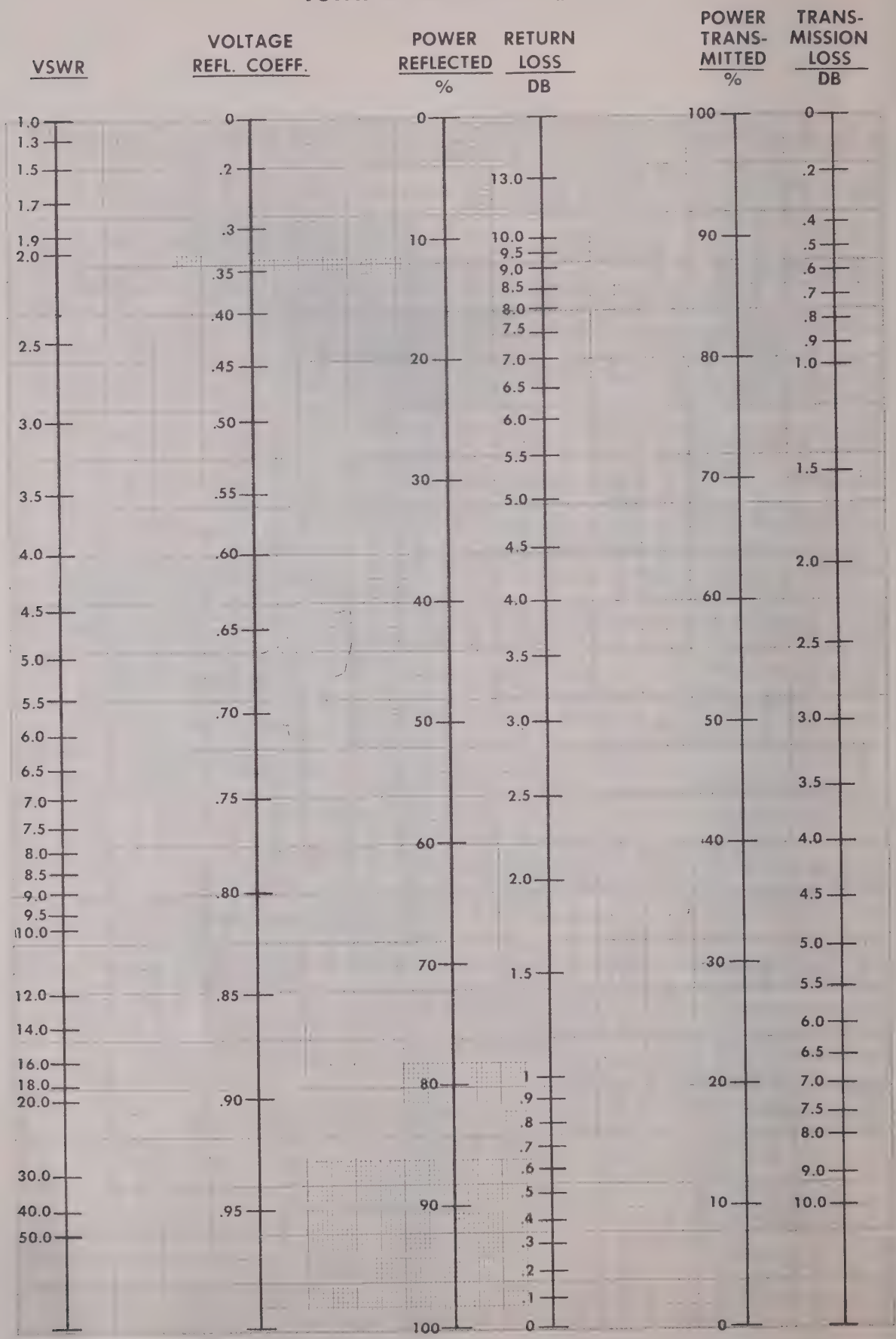
5-3 OUTPUT VSWR

Use the standard VSWR AUTOTESTER or VSWR BRIDGE in the test set-up of Figure 2-1. Calibrate the system with the 20 dB return loss graticule and attenuator pad over the deisred frequency range. Remove the 20 dB pad, then couple the DEVICE UNDER TEST ports of the two VSWR AUTOTESTERS or VSWR BRIDGES together with two GR 900 - QNP adapters. Terminate the RF INPUT port of the VSWR AUTOTESTER or VSWR BRIDGE on test with the standard termination via a coaxial adapter. The VSWR indicated on the oscilloscope graticule should be less than the specification of Table 1-1.

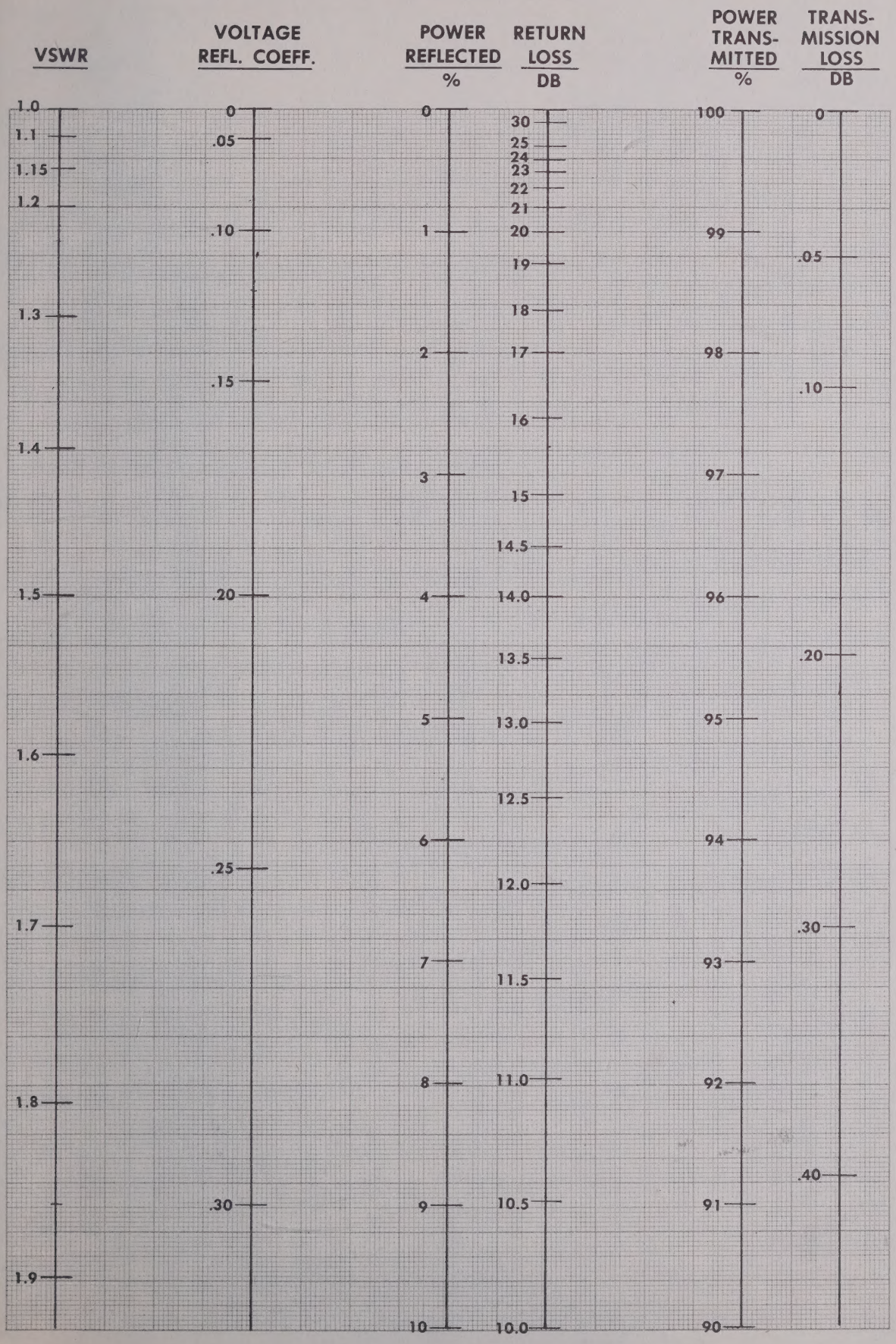
5-4 MAINTENANCE

No customer maintenance is recommended for VSWR AUTOTESTERS or VSWR BRIDGES. If any problems are found, contact your local WILTRON engineering representative for factory service.

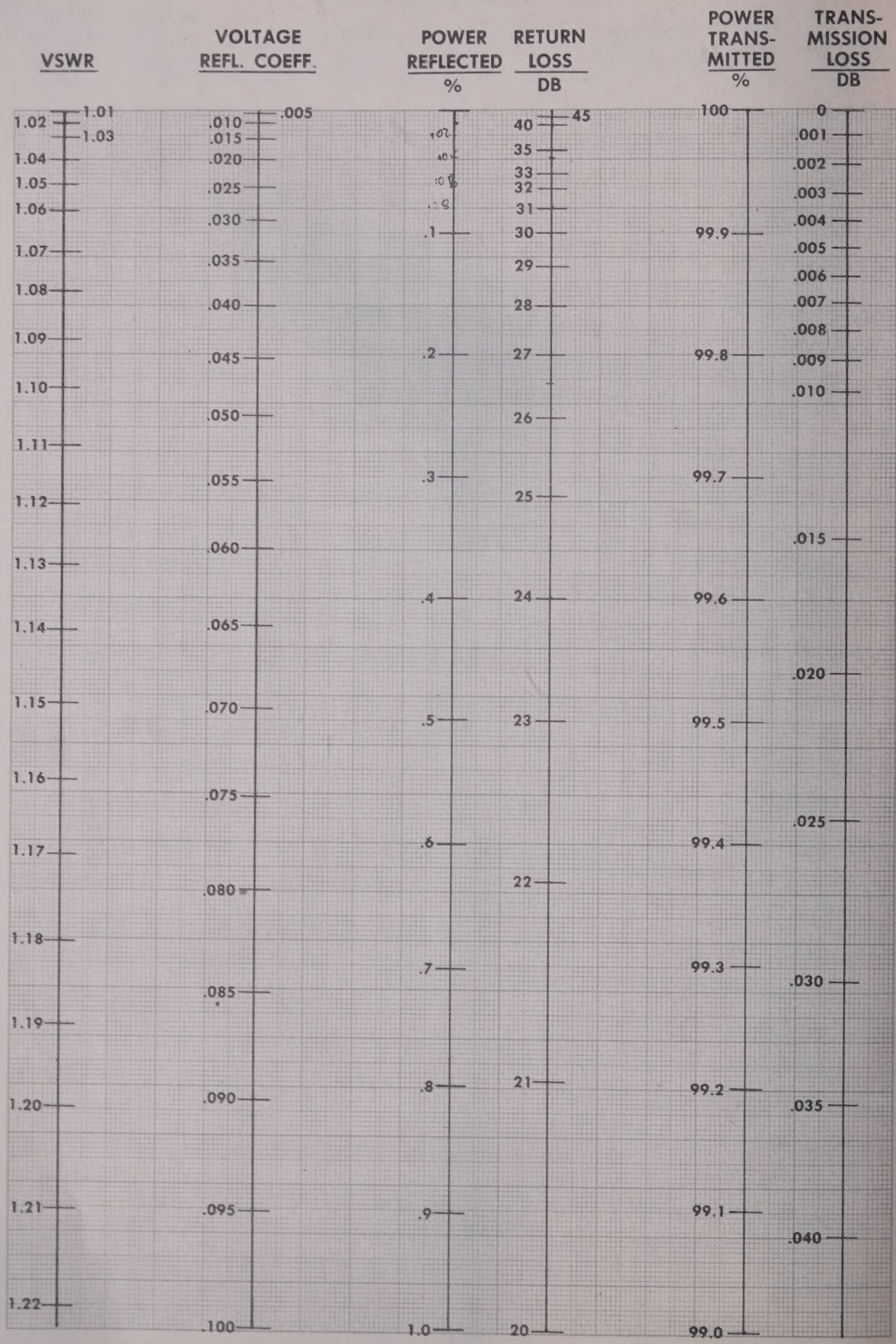
VSWR NOMOGRAPH # 1

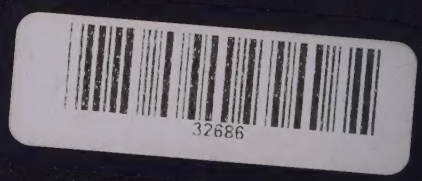


VSWR NOMOGRAPH # 2



VSWR NOMOGRAPH # 3




32686